

## High-speed Photometric Observations of ZZ Ceti White Dwarf Candidates

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**Abstract.** We present high-speed photometric observations of ZZ Ceti white dwarf candidates drawn from the spectroscopic survey of bright DA stars from the Villanova White Dwarf Catalog by Gianninas et al., and from the recent spectroscopic survey of white dwarfs within 40 parsecs of the Sun by Limoges et al. We report the discovery of six new ZZ Ceti pulsators from these surveys, and several photometrically constant DA white dwarfs, which we then use to refine the location of the ZZ Ceti instability strip.

### 1. Introduction

We have recently completed two major spectroscopic surveys of DA stars using the spectroscopic approach where hydrogen Balmer lines are fitted with the predictions of detailed model atmospheres. Gianninas et al. (2011) conducted a spectroscopic survey of over 1300 bright ( $V < 17.5$ ), hydrogen-rich white dwarfs based largely on the last published version of the McCook & Sion catalog (McCook & Sion 1999). The Gianninas et al. sample included 56 known ZZ Ceti stars, 145 photometrically constant DA stars as well as several white dwarfs whose atmospheric parameters placed them within or near the empirical boundaries of the ZZ Ceti instability strip (see Figure 35, Gianninas et al. 2011). This includes the ultra-massive ZZ Ceti star, GD 518 (WD 1659+662), discovered by Hermes et al. (2013). More recently, Limoges et al. (2013, 2014) performed an exhaustive spectroscopic survey of the SUPERBLINK proper motion database (see Lépine & Shara 2005, and references therein) aimed at obtaining a complete sample of white dwarfs in the solar neighborhood within 40 pc of the Sun. Several ZZ Ceti white dwarf candidates were also identified in this survey.

## 2. Atmospheric Parameters

The optical spectra for our ZZ Ceti candidates have been secured using the Steward Observatory 2.3 m telescope equipped with the Boller & Chivens spectrograph. This provides wavelength coverage from  $\lambda \approx 3800\text{--}5200\text{ \AA}$  with a resolution of  $6\text{ \AA}$  FWHM.

In Table 1, we present the effective temperature,  $T_{\text{eff}}$ , and surface gravity,  $\log g$ , for each star. These parameters were measured using the standard spectroscopic technique developed by Bergeron et al. (1992), with recent improvements presented in Liebert et al. (2005) and Gianninas et al. (2011). These fits were performed using our most recent grid of model atmospheres, based on the  $ML2/\alpha = 0.7$  version of the mixing-length theory.

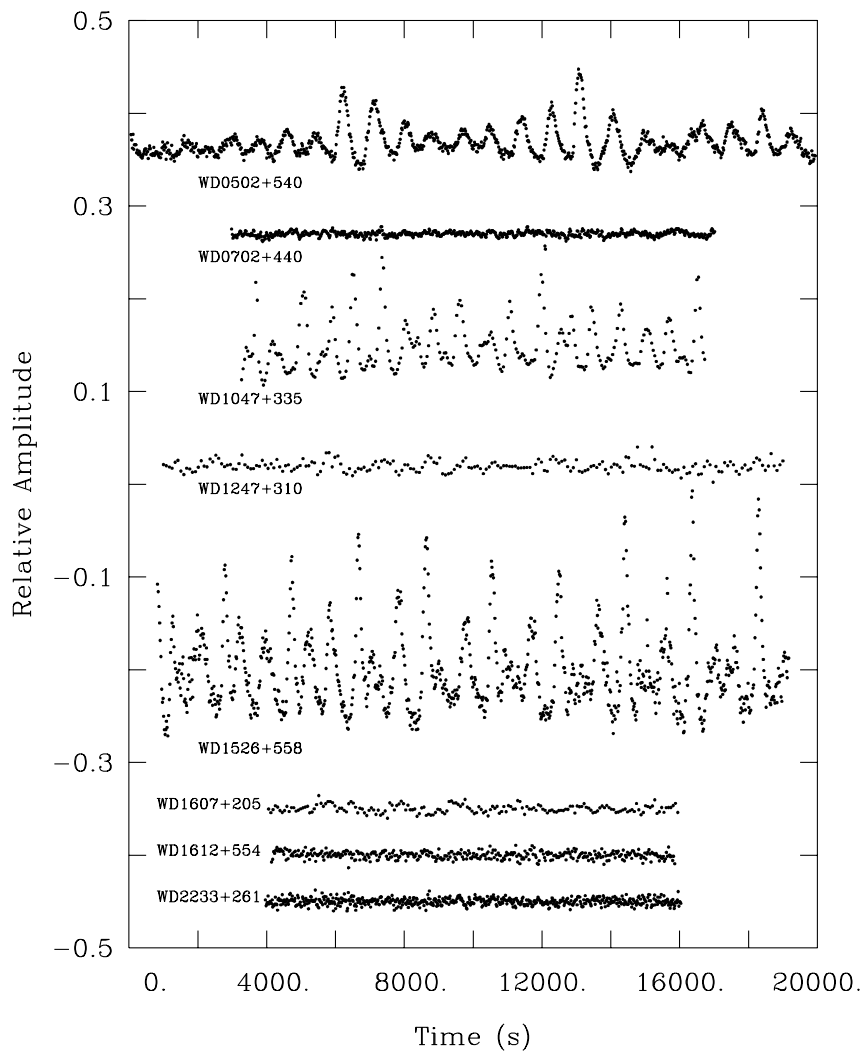


Figure 1. Light curves of our ZZ Ceti white dwarf candidates.

Table 1. Observations of ZZ Ceti Star Candidates

WD	$V$ or $B$ (mag)	$T_{\text{eff}}$ (K)	$\log g$	Length (hr)	Bandpass (mHz)	Period (s)	Amplitude (%)	$4\sigma$ (%)
0502+540	15.2	11400	8.24	9.18	0–5	873.6	1.27	0.41
0702+440	15.1	11000	8.29	15.05	0–10	1366.4	0.10	0.07
1047+335	17.0	11430	8.24	4.59	0–10	767.5	2.77	0.25
1247+310	17.2	12110	8.43	9.76	0–4.5	364.6	0.20	0.20
1526+558	17.0	11020	7.89	5.14	0–10	648.9	3.68	0.26
1607+205	17.4	11280	7.94	9.35	0–7.5	1928.5	0.18	0.13
1612+554	16.5	12100	8.33	3.26	0–10	NOV	...	0.14
2233+261	15.3	12020	8.16	9.82	0–10	NOV	...	0.07
1659+622	16.0	13050	8.06	6.66	0–10	NOV	...	0.12

### 3. High-Speed Photometry and Fourier Analysis

We obtained high-speed photometric measurements of our ZZ Ceti white dwarf candidates using Steward Observatory’s 1.55 m Kuiper telescope on Mt. Bigelow and the Mont4K CCD camera<sup>1</sup> through a Schott-8612 “white light” filter, with the exception of WD 1526+558, which was observed at the Kitt Peak 2.1 m telescope. The observed light curves of our ZZ Ceti white dwarf candidates (except WD 1659+622), are shown in Figure 1. The total time spent on each target is given in Table 1.

We then proceeded to compute the Fourier transforms of our light-curves in order to perform preliminary frequency extraction for the variable stars, and obtain limits on the non-variability for the photometrically constant stars. The results of this analysis are presented in Table 1 where we list the observed bandpass along with the dominant period and its amplitude, expressed as a percentage of the mean brightness of the star. We also list our detection threshold which corresponds to four times the mean noise level within the observed bandpass ( $4\sigma$ ).

### 4. Updated ZZ Ceti Instability Strip

Our updated  $T_{\text{eff}}$  vs.  $\log g$  distribution for DA white dwarfs with high-speed photometric measurements is plotted in Figure 2. The new/known ZZ Ceti stars and new/known constant stars are indicated by different symbols (see the legend at the top of the figure). The dotted lines represent the approximate empirical boundaries of the instability strip based on our new results. The error bars represent the average uncertainties of the spectroscopic method in the region of the ZZ Ceti instability strip. The high- $\log g$  ZZ Ceti star at the bottom of the plot, GD 518, has been reported by Hermes et al. (2013).

There are two non-variable stars located in the middle of the instability strip. The first one is WD 2233+261, and good photometric limits were obtained (see Table 1).

<sup>1</sup>Please consult the following Web site: <http://james.as.arizona.edu/~psmith/61inch/instruments.html> for more details, if interested.

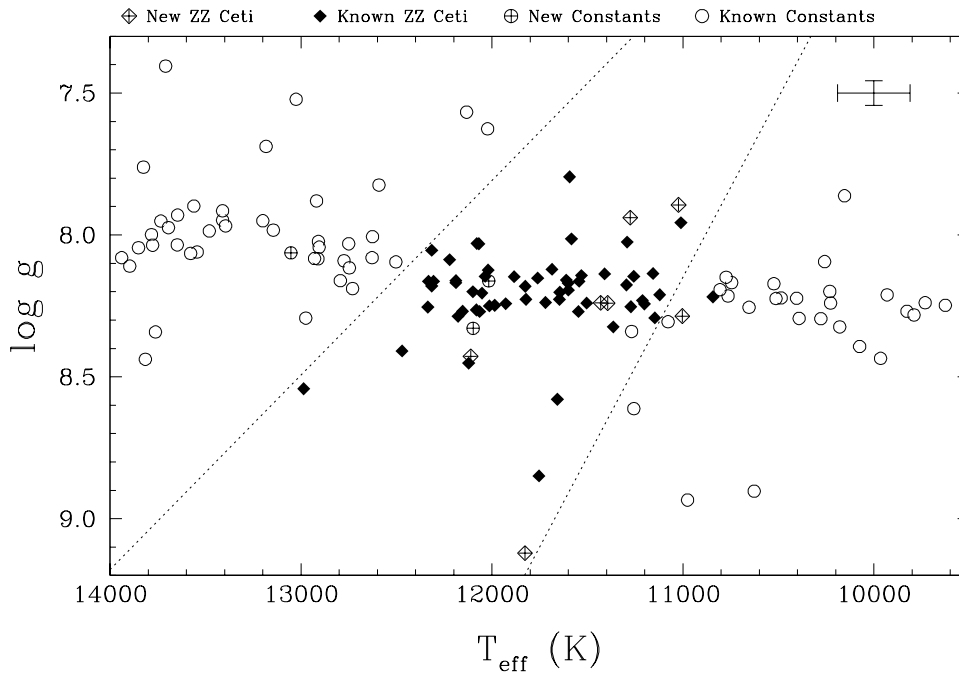


Figure 2. Effective temperature vs. surface gravity distribution for DA white dwarfs with high-speed photometric measurements.

However, only a single spectrum was secured for this object, which thus deserves to be further investigated.

The other offending star is HS 1612+5528 (WD 1612+554), one of the two NOV white dwarfs lying in the heart of the instability strip. Independently observed several times in spectroscopy and high-speed photometry (see Gianninas et al. 2011), HS 1612+5528 could represent the first ZZ Ceti star whose pulsations are hidden from us due to geometric considerations. Alternatively, it could be a double degenerate binary, with individual components located outside the instability strip. This object also merits further study.

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